Title: The Cyclotron

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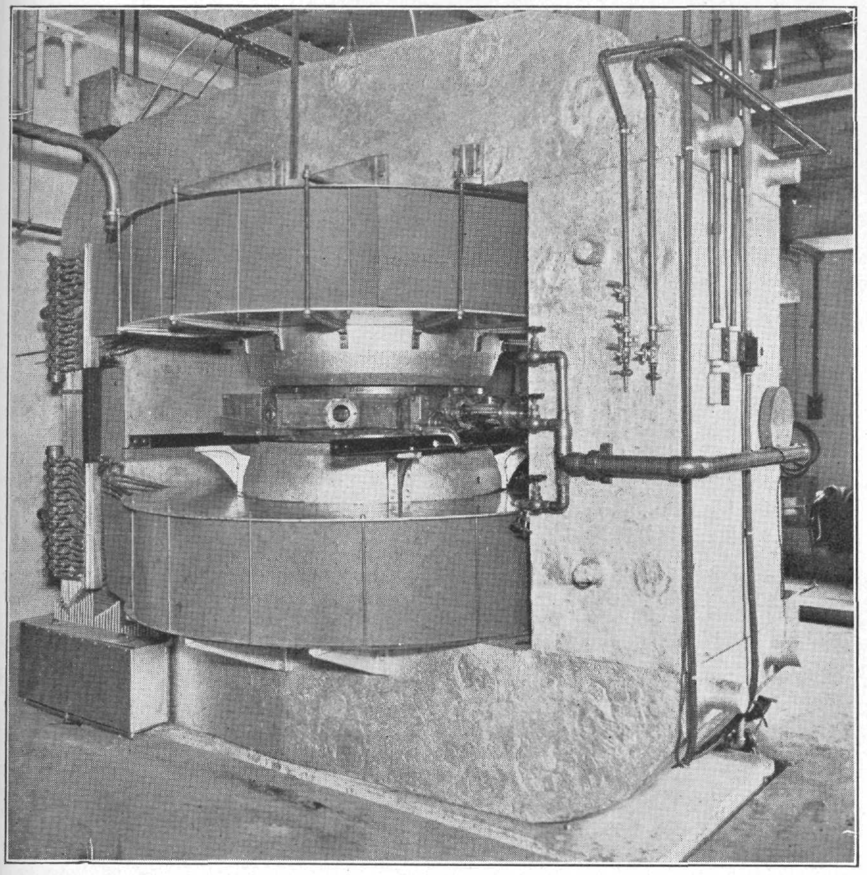

Courtesy Engineering Experiment Station News

• The Cyclotron of Ohio State University.
Note 42-inch vacuum chamber and magnet.

The Cyclotron

By
JOSEPH G. SAYRE
E. E. III

Probably the first attempts at breaking up the atom were conducted with the Van de Graaff high voltage generator. This apparatus brought the possibility of smashing the atom out of the purely theoretical stage onto a workable premise. Men of science hoped that through its use the alchemist's dream of the transmutation of metals into gold might come true. It has long been an accepted theory that the binding force in the atom is electrical in nature. On that hypothesis physicists tackled anew the problem of smashing the atom, aided by Graaff's powerful machine.

Bigger and even more powerful generators were constructed and tested. But it was becoming more and more evident that the atom smashing problem would have to be met with a more powerful weapon of less cumbersome construction. The Van de Graaff generator was too huge and dangerous to work with. The energies which could produce were still too limited and so scientists once more began a search for a new machine that could smash the atom.

One physicist in particular, Professor E. O. Lawrence of the University of California, was working on an atom smasher which would use as an impelling mechanism, an alternating circular magnetic field. It was his contention that by having the bombarding particles travel in a confined circular path he could obtain unknown speeds in these particles. His first model, although only four inches in diameter, conclusively proved the practicability of his theory. The greatest difficulty in the construction of a practical working cyclotron lay in finding a magnet powerful enough. After many considerations the first cyclotron was constructed, using an old thirty-five ton electromagnet, originally designed for a radio transmitter.

The Principle of the Cyclotron

The principle involved in the construction and operation of the cyclotron follows a very logical line of thought. Lawrence supported the idea of hitting the atom with particles of like size matter moving at great velocities. He assumed that if atoms could be hit by very minute particles traveling at a terrific rate the structure of the atom surely would be disarranged to some extent, just as a block of wood is shattered by a bullet. These particles used in the cyclotron are usually heavy hydrogen ions; that is, hydrogen atoms that have lost their outer electron and became protons of hydrogen. The source of these heavy hydrogen atoms is deuterium oxide, commonly known as heavy water.

When an atom of an element is hit by one of these protons, it may do one of several possible things. First it may accept the proton into its nucleus (thus changing its mass and atomic weight), while keeping many of its original properties. If the binding force in the atom itself is not great enough to withstand the impact of the proton, the atom will split into new atoms each with their own systems of electrons. Often the bombarded atom refuses either to accept the bombarding particles into its system or to break up into new atoms, but merely "boards" the proton long enough to convert it into energy. Since the atom has no real need for this extra energy, it starts to give energy back immediately in much the same manner as radium. This condition, which has been created in practically every metal known, is referred to as artificial radioactivity.

Construction of the Cyclotron

The cyclotron proper can best be described as several separate units, although its operation depends upon the exact coordination of these units.

The cyclotron does not create energy, but merely uses electrical energy as a medium for imparting controlled motion to the hydrogen protons. Most of the cyclotrons in use today are powered by their own generating units. One of the largest units is that of the famous Cavendish cyclotron. Its current supply consists of three huge generators and an elaborate rectifying system much like that of a radio station, as the current produced by these generators is changed to a high frequency before being used by the cyclotron. This powerful cyclotron uses a 100 KW unit and produces a current of 12 megacycles or a wave length of 25 meters.

The hollow semi-circular cylinders or electrodes of brass in which the particles revolve are called "dees." These dees are so constructed that it is possible to evacuate the air from them during operation as the collisions of the bombarding particles with the air molecules greatly decreases the energy of the particles. The dees are located between the poles of the electromagnet. The alternating current field applied by the magnet causes the positively charged protons to revolve inside the dees with increasing velocity and kinetic energy.

The remaining major unit is the deflector magnet. This unit is located on the outside edge of one of the dees. This deflector magnet serves not only to pull the bombarding particles out of the dees, but it also serves to focus and concentrate this beam of deuterons, or heavy hydrogen protons.

The preparation of the target sample for bombardment at one time presented a difficult problem. The early atom smashers were inconvenient to use since the target was located inside the acceleration chamber, necessitating the opening and closing of this chamber for mounting the target sample. On the present day cyclotron the target is located directly in front of the exit window, being fastened to the outside of the chamber on the target plate. This plate incorporates a specially built water cooling jacket which efficiently carries away the huge quantities of heat generated.

The final step before actual bombardment is begun is the introduction of the bombarding particles into the center of the chamber. As the heavy hydrogen gas is admitted into the dees, the electronic field immediately knocks off the outer electron of the hydrogen atom leaving a positively charged nucleus. Upon securing this positive charge the deuteron is attracted by the negatively charged dee and repulsed by the positively

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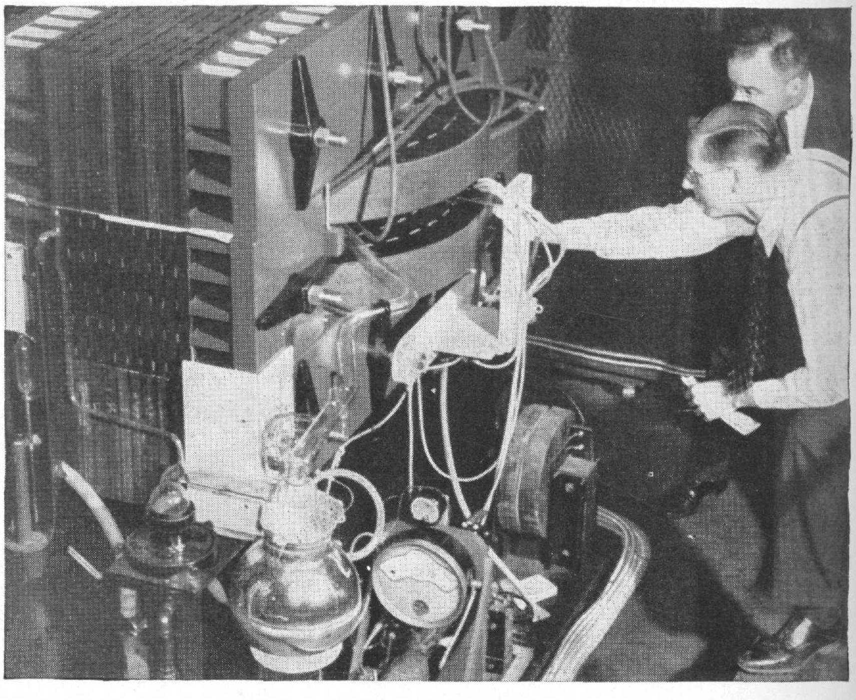

THE BETATRON

The counterpart of the cyclotron. It is used to accelerate electrons instead of protons.

Courtesy General Electric

THE CYCLOTRON

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charged one. As the charge on each dee respectively alternates the deuterons begin to traverse a circular path inside the dees. The increase in velocity causes the diameter of this path to become greater and greater. When these deuterons have secured their maximum velocity, they are traveling at the outermost edge of the dees. Here they become attracted by the highly negatively charged (10,000 volt) deflector plate. Finally this attraction becomes so great that the particles fly off past the deflector plate, tangent to the dees. It is estimated that the majority of particles travel one hundred revolutions or more before they are pulled out for bombardment.

This deuteron beam is extremely powerful and dangerous if not controlled. It very nearly approaches the "disintegrator" ray of fiction. Water placed in the path of the high velocity deuterons is exploded to superheated steam by the tremendous energy of the deuterons.

After the bombardment of the target the problem of identifying the wreckage is the major consideration. Part of the sample is turned over to the chemist for standard analysis (including the use of the spectrograph) to determine its composition. If the substance has become radioactive during the process of bombardment, a device known as the Geiger counter is also employed in determining its composition.

Uses of the Cyclotron

The newest use of the cyclotron is in the production of artificially radioactive substances. These substances find unlimited use as "tracers" in plant processes and human diseases. By injecting artificially radioactive phosphorus, for example, into certain bacteria, it is possible to actually follow the course of the bacilli as they seek their way into tissues.

Professor Lawrence, aided by his cyclotron, has made several remarkable discoveries which are aiding greatly in the understanding of those diseases such as cancer. He has discovered that different types of cancer cells assimilate the element phosphorus at different rates, thus introducing a new method for the possible identification and classification of these cells. It has also been found practical to use artificially radioactive substances in place of radium for effective treatment of cancer. These "artificial radiums," produced by bombardment of certain material, are not only much less expensive and less difficult to secure, but their activity can be limited, thus reducing many of the dangers that often arise from the use of natural radium. Professor Lawrence has found that these radioactive materials in many cases are much better for treatments than radium. The rays produced by these substances act with much greater force and selectivity than X-rays. In experiments on animals it was found that these rays were anywhere up to five times more lethal to tumor tissues than radium, yet the normal tissues in that vicinity were not as much injured by the artificial materials as when radium was used for treatment.

The greatest use for the cyclotron outside of the medical field is in investigating a way for unlocking the tremendous energies contained in the nucleus of the atom. As an aid in visualizing this energy consider the energy required to change the structural form of the atom, let alone convert it into energy. The ultimate goal is to change the mass of the atom into energy, and physicists believe that the cyclotron is the machine that can do it—if anything can. Reasonably accurate calculations on the basis of past experiments with the cyclotron show these quantities of energy are actually unbelievable.

New Cyclotron

Construction of the world's largest cyclotron under the direction of Professor Lawrence is now under way. This machine will surpass any of its kind ever built. The new cyclotron will be about the size of a small home, measuring about 34 x 25 x 13 feet. The pole pieces of its magnet and dees will measure about eleven feet across. Into this magnet's windings will go some 244 tons of copper wire. The total weight of the installation will be in the neighborhood of two thousand tons, double the size of the largest cyclotron now existing. With this cyclotron, physicists will generate 100,000,000 electron volts to hurl at the heart of the atom. Its 140 foot deuteron beam will render the utmost destruction to the targets.

Because of its power, the new cyclotron is being built on an isolated hill far away from any Californian homes. If too many difficulties do not arise, the new atom smasher will be completed in the next two or three years. It is costing $1,500,000, $1,150,000 of which has been granted by the Rockefeller Foundation. The control room of the new cyclotron will be located 150 feet from the cyclotron itself, thus eliminating many of the dangers from radiations.

The possibilities of the new cyclotron are unlimited. Professor E. O. Lawrence has said:

> A simple calculation according to the relativity theory shows that a glass of water if completely destroyed and converted into useful energy, would yield more than a billion kilowatt hours of electricity, enough to supply light and power for quite some time.

In the future the secret of the atom and the practical application of the energy contained therein may be unlocked to do man's work—and the cyclotron may be the key to that lock.